the rainfall stands for a considerable time after falling.

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SPECIAL ARTICLES.

THE AVAILABILITY OF CELLULOID IN ILLUSTRATING CHROMATIC POLARIZATION.

1. It is not unusual to find that celluloid shows brilliant colors between crossed nicols on the cut edges. This observation suggested the use of the material to illustrate the properties of plates cut parallel to the optic axis, when seen in polarized light in the usual way. In fact, if a strip of celluloid is evenly stretched, fields of color vying in brilliancy with those of the natural crystal, may be obtained quite uniformly over an area an inch or more square, and variable at will through two or more well-defined orders; or the color of any given crystal may be similarly increased or decreased continuously in order. The well-known complicated figures seen in compressed or annealed glass are thus simplified, in a way that is at once interpretable in terms of elementary optical theory.

2. In the following experiment I used strips of clear celluloid, about 20 cm. long, 1 cm. or less broad (to avoid the need of excessive traction) and but .025 cm. thick (for flexibility). They were mounted between rollers, very much in the manner used in film cameras, except that one roller was rigidly fastened while the other could be rotated by the aid of a lever and clamped. If many strips are to be simultaneously stretched, it is advisable to secure one end of the strip under a plate of brass, bringing the ends around the remote edge and holding them down under a second smaller plate, in order that the maximum of friction may be encountered. The roller in this case is preferably a strong hollow brass cylinder (say 2 cm. in diameter) with a central longitudinal slot. Through this the ends are passed and wedged in place with a conical rod forced into the inside of the tube. About one complete turn should be taken to insure friction. For special purposes instanced below, a similar adjustment for stretching at right angles to the preceding should be added. Screw apparatus or uniform loads are also useful in particular cases.

3. As the two directions of vibration are parallel to the strain and at right angles to it, respectively, the nicols may be adjusted at 45 degrees to the vertical and the pulls be either horizontal or vertical. The phase difference ϕ for a thickness of strip, d, being

$$\phi = 2\pi d (n - n') \lambda,$$

where n and n' are the two indices of refraction for light of normal wave-length, λ. The plan of experiment consists in varying $n - n'$ continuously from 0 by increasing stress as far as the breaking point of the strip, and to increase d successively from the thickness of 1 to that of four strips ($d = .025$ to .1 cm.). The following results may be recorded:

One strip, $d = .025$ cm. Colors whitish to middle of the first order. When the strip breaks, the efficiency does not much exceed a quarter wave-length plate. Such a plate of mica, where mean and minimum elasticities are involved, is but $d = .0032$ cm. thick; a similar plate of selenite, where maximum and minimum elasticities occur, is .0027 cm. thick for mean wave-lengths. Hence the efficiency of a strip of celluloid stretched nearly to the breaking point is for like thicknesses, about 13 per cent. of that of mica and 10 per cent. of that of selenite.

Two strips, $d = .050$ cm. The earlier whitish colors now become more and more saturated and the strips break about at the end of the order.

Three strips carry the phenomenon (when stress is gradually increased) from colorless to the middle of the second order, extremely vivid colors overlying the whole visible area of the strip; four strips complete the first two series. If more strips are to be used the machine must be strong and quite perfect in its clutch, otherwise there is slipping and abrasion, by which the strength of the strips is decreased. Apart from this the experiments may be carried into higher orders of color at pleasure.

4. *Special Experiments.*—If three or four strips of successively decreasing width overlie each other symmetrically, so as to form a

steplike double or single wedge in cross section, the appearance is very striking, each thickness glowing with its particular color.

To produce a continuous wedge effect, the width of the strips should be gradually decreased to the center of the field. Since stress is greatest where the cross-section is least, the higher orders of colors appear nearer the center.

5. *Compensation Effects.*—If a plate quartz, cut parallel to the axis and showing the warm red between crossed nicols, is placed with its axis parallel to the lines of strain of the celluloid strip, the succession of colors is red, orange, yellow, green, blue or retrograde. The quartz effect is thus gradually more and more neutralized by the celluloid strip as its strain increases. If the axis of the quartz plate is at right angles to the lines of strain, the order is red, purple, blue, green, yellow or direct. The quartz and celluloid effect coincide in sign. Hence the ray vibrating in the direction of the lines of stress corresponds to the ordinary ray in quartz, which from the positive character of the wave surface, is the swifter. It follows that the ray vibrating parallel to the lines of stress of the celluloid strip moves with greater velocity than the ray vibrating normally to this direction. In other words the extraordinary ray is swifter and the wave surface of strained celluloid is negative: for on inclining the celluloid strip around the lines of stress as an axis, the succession of colors (due to increasing thickness) is direct in order; whereas on inclining the strip around an axis normal to the lines of stress the succession is actually retrograde, showing that the optic axis is being rapidly approached, where double refraction ceases in spite of thickness.

Similarly if a quarter wave plate of mica is inserted with the effective axis parallel to the lines of stress, the order of colors for crossed nicols is bluish, dark (neutral, compensation), bluish, yellowish, etc. (excessive celluloid effect), or clearly retrograde. If inserted with the axis normal to the lines of stress the succession of color is bluish, yellowish, red, purple, blue, etc., or direct, all of which admits of the same interpretation as in the case of quartz.

An equally interesting compensation is obtained by crossing two similarly stretched strips of celluloid at right angles. In this case the area where the strips overlap is quite neutral (dark between crossed nicols) while the four non-duplicated areas, extending outward from the square center, are vividly colored. The faster ray in one strip becomes the slower in the other, and *vice versa.*

My thanks are due to Professor Barus, who suggested these experiments, for his aid throughout the whole course of the work.

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AMŒBA BLATTÆ AND AMŒBOID MOTION.

THE writer wishes to call the attention of teachers of biology to a form of *Amœba* that hitherto has been somewhat neglected in this country, but which is of much theoretical interest. It is, moreover, sufficiently plentiful and easily obtained at all seasons of the year to be adapted to the uses of small laboratory classes. This is *Amœba blattæ* Bütschli, which inhabits the intestine of the croton bug, or common cockroach, *Blatta* (*Phyllodromia*) *germanica,* a well-known immigrant from Europe that has established itself in our larger towns and, at least in the eastern states, in many country villages. Throughout the year this cockroach is active in bake-shops, creameries, sugar refineries and in the kitchens and basements of hotels, restaurants and private houses, where it may be found under sinks, about water pipes and in similar warm, dark places.

Rhumbler,[1] in a recent paper in the 'Festschrift' commemorating Professor Ernst Ehler's seventieth anniversary, describes fully the movements of this *Amœba,* as well as the methods that have been employed at Göttingen for obtaining it. The cockroaches are etherized, the heads and terminal segments of the abdomen clipped off, and the intestine care-

[1] Rhumbler, L., '05, 'Zur Theorie der Oberflächenkräfte der Amöben,' *Z. f. wiss. Zool.*, 83 Bd., pp. 1–52.